MULTIPURPOSE HEALTH CARE TELEMEDICINE SYSTEM

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Abstract- **In this study we present a multipurpose health care telemedicine system, which can be used for emergency or patient monitoring cases. Ambulances, Rural Health Centers (RHC) or other remote health location, Ships navigating in wide seas and Airplanes in flight are common examples of possible emergency sites, while critical care telemetry and telemedicine home follow-ups are important issues of patient monitoring. The telemedicine system is a combined real-time and store and forward facility that consists of a base unit and a telemedicine (mobile) unit. The telemedicine unit (patient site) allows the transmission of vital biosignals (3-12 lead ECG, SPO2, NIBP, IBP, Temp) and still images of the patient from the incident place to the base unit (consultation site). The transmission is performed through GSM, Satellite links or POTS. Using this device a specialist doctor can telematically "move" to the patient site and instruct medical personnel when handling a patient. The consultation site is equipped with a multimedia database able to store and manage the data collected by the system. The system was validated in four different countries using a standardized medical protocol.**

Keywords – **Emergency Health Care Telemedicine, GSM, Satellite, POTS**

I. INTRODUCTION

The availability of prompt and expert medical care can meaningfully improve health care services at understaffed rural or remote areas. The provision of effective emergency Telemedicine and home monitoring solutions are the major fields of interest discussed in this study. There are a wide variety of examples where those fields are crucial. Nevertheless, *Ambulances*, *Rural Health Centers* (RHC) or other remote health location, *Ships* navigating in wide seas and *Airplanes* in flight are common examples of possible emergency sites, while *critical care telemetry and Telemedicine home follow-ups* are important issues of telemonitoring. In emergency cases where immediate medical treatment is the issue, recent studies conclude that early and specialized pre-hospital patient management contributes to the patient's survival [1]. Especially in cases of serious head injuries, spinal cord or internal organs trauma, the way the incidents are treated and transported is crucial for the future well being of the patients.

A quick look to past car accident statistics points out clearly the issue: During 1997, 6753500 incidents were reported in the United States [2] from which about 42000 people lost their lives, 2182660 drivers and 1125890 passengers were injured. In Europe during the same period 50000 people died resulting of car crash injuries and about half a million were severely injured. Furthermore, studies completed in 1997 in Greece [3], a country with the world's third highest death rate due to car crashes, show that 77,4 % of the 2500 fatal injuries in accidents were injured far away

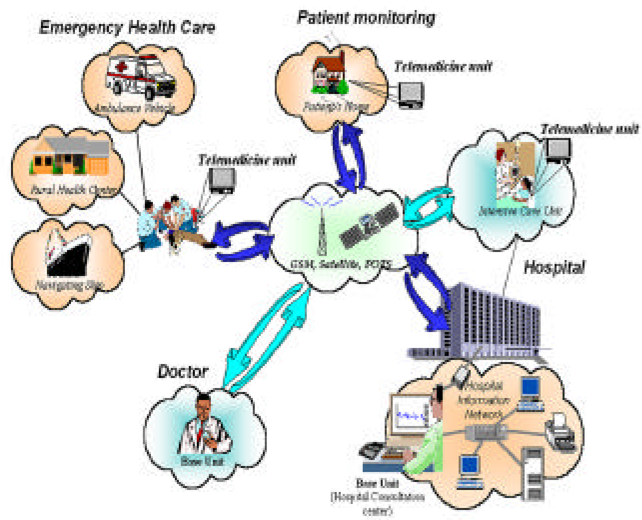

Fig 1. Overall system architecture

from any competent healthcare institution, thus resulting in long response times. In addition, the same studies reported that 66% of deceased people passed away during the first 24 hours.

Coronary artery diseases is another common example of high death rates in emergency or home monitoring cases since still two thirds of all patients die before reaching the central hospital. In a study [4] in the UK in 1998, it is sobering to see that among patient above 55 years old, who die from cardiac arrest, 91% do so outside hospital, due to a lack of immediate treatment. In cases where thrombolysis is required, survival is related to the "call to needle" time, which should be less than 60 minutes [5]. Thus, time is the enemy in the acute treatment of heart attack or sudden cardiac death (SCD).

Critical care telemetry is another case of handling emergency situations. The main point is to monitor continuously intensive care units' (ICU) patients at a hospital and at the same time to display all telemetry information to the competent doctors anywhere, anytime[6]. Having a closer look at the basic Telemedicine process nothing is changer except from the fact that in this the doctor is the one remotely located, while the emergency site is at a stable point (the hospital).

Another important Telemedicine application field is home monitoring. Recent studies show that [7] the number of patients being managed at home is increasing, in an effort to cut part of the high hospitalization's cost, while trying to increase patient's comfort[7].

It is common knowledge that people that monitor patients at home or are the first to handle emergency situations do not always have the required advanced theoretical background

Report Documentation Page

Report Date	Report Type	Dates Covered (from... to)
25 Oct 2001	N/A	-

Title and Subtitle Multipurpose Health Care Telemedicine System	**Contract Number**
	Grant Number
	Program Element Number
Author(s)	**Project Number**
	Task Number
	Work Unit Number
Performing Organization Name(s) and Address(es) Biomedical Engineering Laboratory Department of Electrical and Computer Engineering National Technical University of Athens (NTUA) Athens, Greece	**Performing Organization Report Number**
Sponsoring/Monitoring Agency Name(s) and Address(es) US Army Research, Development & Standardization Group (UK) PSC 802 Box 15 FPO AE 09499-1500	**Sponsor/Monitor's Acronym(s)**
	Sponsor/Monitor's Report Number(s)
Distribution/Availability Statement Approved for public release, distribution unlimited	
Supplementary Notes Papers from 23rd Annual International Conference of the IEEE Engineering in Medicine and Biology Society, October 25-28, 2001, held in Istanbul, Turkey. See also ADM001351 for entire conference on cd-rom. , The original document contains color images.	
Abstract	
Subject Terms	
Report Classification unclassified	**Classification of this page** unclassified
Classification of Abstract unclassified	**Limitation of Abstract** UU
Number of Pages 4	

and experience to manage properly all cases. Emergency Telemedicine and home monitoring can solve this problem by enabling experienced neurosurgeons, cardiologists, orthopedics and other skilled people to be virtually present in the emergency medical site. This is done through transmission of vital biosignals and on scene images of the patient to the experienced doctor.

In order to meet the above different growing demands we created a combined real-time and store and forward facility that consists of a base unit and a telemedicine unit where this integrated system:

- Handles emergency cases in ambulances, RHC or ships by using the Telemedicine unit at the emergency site and the expert's medical consulting at the base unit
- Enhances intensive health care provision by giving the telemedicine unit to the ICU doctor while the base unit is incorporated with the ICU's in-house telemetry system
- Enables home telemonitoring, by installing the telemedicine unit at the patient's home while the base unit remains at the physician's office or hospital.

The Telemedicine device is compliant with some of the main vital signs monitor manufacturers like Critikon (Johnson & Johnson) and Propaq. It is able to transmit both 3 and 12 lead ECGs, vital signs (non-invasive blood pressure, temperature, heart rate, oxygen saturation and invasive blood pressure) and still images of a patient by using a great variety of communication means (Satellite, GSM and Plain Old Telephony System - POTS). The base unit is comprised of a set of user-friendly software modules that can receive data from the Telemedicine device, transmit information back to it and store all data in a database at the base unit. The communication between the two parts is based on the TCP/IP protocol.

II. Methodology

As mentioned above, scope of this study was to design and implement an integrated Telemedicine system, able to handle different Telemedicine needs. In other words we determined an "all-weather" system consisting of two major parts: a) a Telemedicine unit (which can be portable or not portable depending on the case) and b) a base unit or doctor's unit (which can be portable or not portable depending on the case and usually located at a Central Hospital). Fig 1 describes the overall system architecture.

The *Telemedicine unit* is responsible for collecting and transmitting biosignals and still images of the patients from the incident place to the Doctor's location while the *Doctor's unit* is responsible for receiving and displaying incoming data. The Doctor might be using the system either in an Emergency case or when monitoring a patient from a remote place.

The design and implementation of the system was based on a detailed user requirements analysis, as well as the corresponding system functional specifications. The study was mainly based on the experience of Telemedicine projects named AMBULANCE [8]and Emergency 112 [9]-[10], where functional prototypes of a device with emergency Telemedicine functionalities was built and extensively evaluated. Through these projects we had phased the need to implement an all-purpose telemedicine device.

The software design and implementation follows the client server model; it was done using Borland Delphi 4 for windows 95/98/NT platform; the Telemedicine unit site is the client while the Base unit site is the server. Communication between the two parts is achieved using TCP/IP as network protocol, which ensures safe data transmission and interoperability over different telecommunication means (GSM, Satellite, and POTS). System communications are based on a predefined communication protocol for data interchange, which is used to control and maintain connection between the two sites, thus ensuring portability, interoperability and security of the transmitted data.

a) Telemedicine Unit:

The Telemedicine unit mainly consists of four modules, the biosignal acquisition module, which is responsible for biosignals acquisition, a digital camera responsible for image capturing, a processing unit, which is basically a Personal Computer, and a communication module (GSM, Satellite or POTS modem).

The biosignal acquisition module was designed to operate with some of the most common portable biosignal monitors used in emergency cases or in Intensive care Units such as a) CRITIKON DINAMAP PLUS Monitor Model 8700/9700 family of monitors, b) PROTOCOL Propaq 1xx Vital Signs Monitor, c) PROTOCOL Propaq Encore 2xx Vital Signs Monitor.

The biosignals collected by the patient (and then transmitted to the Base Unit) are: ECG up to 12 lead, depending on the monitor used, Oxygen Saturation (SpO2), Heart Rate (HR), Non-Invasive Blood Pressure (NIBP), Invasive blood Pressure (IP), Temperature (Temp), Respiration (Resp).

The PC used depends on the type of the Telemedicine application (role of the Telemedicine unit). a) in cases where the autonomy and small size of the system are important (mainly in ambulances), a sub notebook like Toshiba libretto 100ct portable PC is used. b) in cases where we need some autonomy but size is not considered an important element a Typical Pentium portable PC is used and c) in cases where we do not necessarily need autonomy, portability and small system size, a Typical Pentium Desktop PC is used.

As mentioned before, data interchange is done using the TCP/IP network protocol, which allows operation over several communication means. The PC is equipped with the proper modem for each case, i.e. GSM, Satellite or POTS. The design was done for standard Hayes modems. The system supports ETSI - AT command set for GSM modem, for Satellite modems and for Standard POTS modems. Several modems types were used for testing: a) a NOKIA card phone 2.0 GSM 900/1800 modem pcmcia card and an Option FirstFone GSM 900 modem pcmcia card were used for GSM communication, b) a Micronet pcmcia POTS modem 56K and a US-Robotics 33.6K external modem were used for POTS communication,

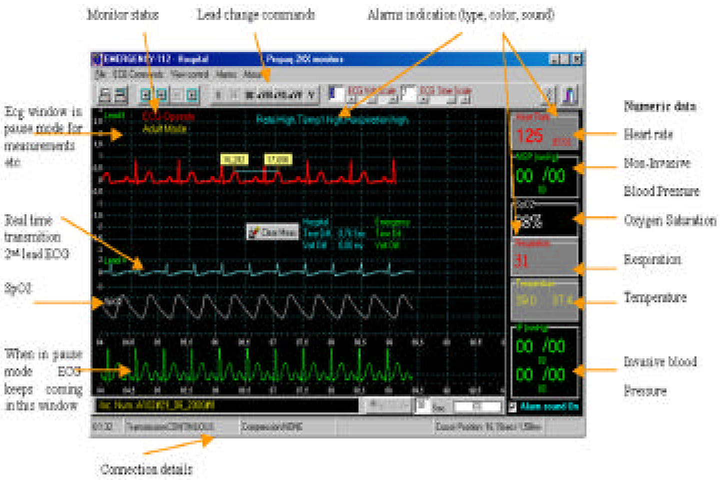

Fig 2. Biosignal receiving window at Base Unit

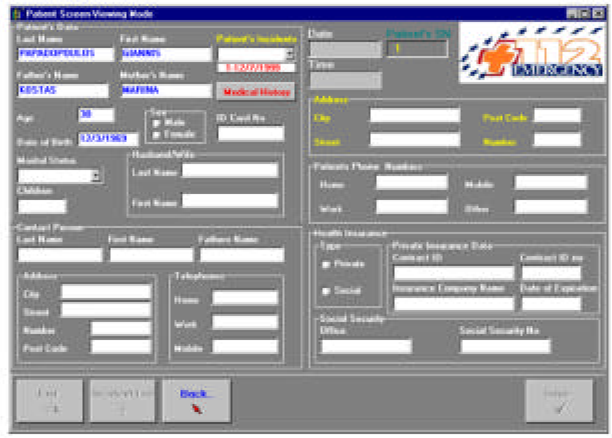

Fig 3. Patient Information window, Hospital database Unit

c) a mini m terminal for ships "Thrane &Thrane TT-3064A CAPSAT Inmarsat Maritime Phone" was used for satellite communication.

The Telemedicine unit is also responsible for the collection and transmission of images of the patient to the base unit. In order to implement a hardware independent system, this module was designed to operate using video for WINDOWS. Several cameras were used while testing the system (ZOOM, Creative, Logitech, Samsung).

The control of the Telemedicine unit is fully automatic. The only thing the telemedicine unit user has to do is connect the biosignal monitor to the patient and turn on the PC. The PC then performs the connection to the base unit automatically. Although the base unit basically controls the overall system operation, the Telemedicine unit user can also execute a number of commands. This option is useful when the system is used in a distance health center or in a ship and a conversation between the two sites takes place.

b) Base Unit (or Doctor's Unit):

The base unit mainly consists of a dedicated PC equipped with a modem, which is responsible for data interchange. In addition the base unit pc is responsible for displaying incoming signals from the Telemedicine unit. When an expert doctor uses the base unit located outside the hospital area (like in the Intensive Care Room application – see Fig 1), a portable PC equipped with a GSM modem or a desktop PC equipped with a POTS modem is used. When the base unit is located in the hospital, a desktop PC connected to the Hospital Information Network (HIS) equipped with a POTS modem can additionally be used; the expert doctor uses it as a processing terminal.

Through the base unit, user has the full control of the telemedicine session. The user is able to monitor the connection with a client (telemedicine unit), send commands to the telemedicine unit such as the operation mode (biosignals or images).

In cases were the base station is connected to a Hospital LAN, the user of the base unit is able to choose and connect to anyone of the telemedicine units connected on the network. The units connected on the network can be ICU telemedicine units or distance mobile telemedicine units connected through phone lines.

The Base Unit's user can monitor biosignals or still images coming from the Telemedicine unit, thus keeping a continuous online communication with the patient site. This unit has the full control of the Telemedicine session. The doctor (user) can send all possible commands concerning both still image transmission and biosignals transmission. Fig 2 presents a typical biosignal-receiving window (continuous operation).

When the system operates on still image mode, the doctor can draw-annotate on the image and send the annotations back to the Telemedicine unit; the user can also annotate on the freezed image and annotations will then again be transferred to the Base unit.

When operating on biosignal mode (Fig 2), the transmission of vital biosignals can be done in two ways, continuous way or store and forward way, depending on the ECG waveform channels which are transmitted and the telecommunication channel data transfer rate. In continuous operation, the Base Unit user can send commands to the Telemedicine Unit monitor, such as lead change or blood pressure determination; the user can also pause incoming ECG, move it forward or backward and perform some measurements on the waveform.

c) Hospital database Unit:

When the Base Unit is located in a hospital (especially in emergency handling or in home telecare), a Hospital database unit can be integrated in the system, in order to record information concerning the cases handled. When the system is used for emergency cases, predefined information for each case are registered, information includes incident's number, date, time, initial and final diagnosis, Telemedicine files etc. This information is compliant to the directive *"Standard Guide for View of Emergency Medical Care in the Computerized Patient Record"* (designation E1744-95) of the American Society for Testing and Materials (ASTM). When the system is used in an Ambulance Emergency Medical

Service, the database unit is also responsible for accepting and recording emergency calls, as well as managing Ambulance vehicle fleet.

In cases where a Hospital Information System (HIS) is already available at the Base Unit site (Hospital), the doctor (Base Unit user) can retrieve information (using the hospital archiving unit) concerning the patient's medical history. When HIS is not available, the Hospital Database Unit can handle the patient medical record by itself (Fig 3).

The database was designed using Paradox 7 and was equipped with graphical user interface features built in Borland Delphi 4 for increased user friendliness. All parts of the database are in compatibility with Microsoft Windows 98/NT. For security reasons, according to the directive 95/46/EC, the database is fully protected against unauthorized access and is password protected and encrypted, whereas the whole application is password protected with several access levels depending on user groups.

III. RESULTS

Implementation of the system has been completed. The system has been demonstrated. All functions were tested, including biosignal, image transfer and white boarding. Four pilot sites in Greece, Italy, Sweden and Cyprus were participating in the demonstration phase. Particularly the demonstration phase was performed at the facilities of the Athens Medical Center (Greece), the Malmo Ambulance Services (Sweden), the Azienda Ospedaliera Pisa (Italy) and Cyprus Ambulance Services (Cyprus). The demonstration was performed on 100 (not severe) emergency cases for each hospital. The results of this phase were very encouraging. The system was able to improve, the percentage of incidents that in an emergency case initial diagnosis did not matched final diagnosis. For 100 cases without the system use, 13% of initial diagnosis did not matched the final diagnosis, while in 100 case with the system use 8% of initial diagnosis did not matched the final diagnosis.

IV. DISCUSSION

The final result is an “all-weather” Telemedicine system, with a flexible architecture that can be adopted in several different application fields. The system has been tested and validated for a variety of medical devices and telecommunication means. The system is currently installed and being used in daily basis in two different countries, Greece and Cyprus.

V. CONCLUSION

We have developed a medical device for telemedicine applications. The device uses GSM mobile telephony links, Satellite links or POTS links and allows the collection and transmission of vital biosignals, still images of the patient and bi-directional telepointing capability. The advance man-machine interface enhances the system functionality by allowing the users to operate in hands-free mode while receiving data and communicating with specialists. Initial results and conclusions are very promising. We intend to improve the system by adding several other functions such as the connection to other medical devices and the application in other cases such as airplanes in flight or trains. Further work is being carried out in integrating the system to hospital HIS/PACS networks.

ACKNOWLEDGMENT

The general framework for the above system was developed under EU funded TAP (Telematics Applications Programme) projects. The Emergency-112 project (HC 4027) and the Ambulance (HC1001). Partners in the projects were ICCS-NTUA (project coordinator), Athens Medical Center, Medical Diagnosis and Treatment, Panafon and Epsilon Software from Greece, R&S Informatica and CPR/Pisa Hospital from Italy, Eurotechnology and Malmo University Hospital in Sweden, University of Cyprus and Nicosia Hospital in Cyprus. We would like to express our thankfulness to all participants in the project for their significant contribution and fruitful collaboration.

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